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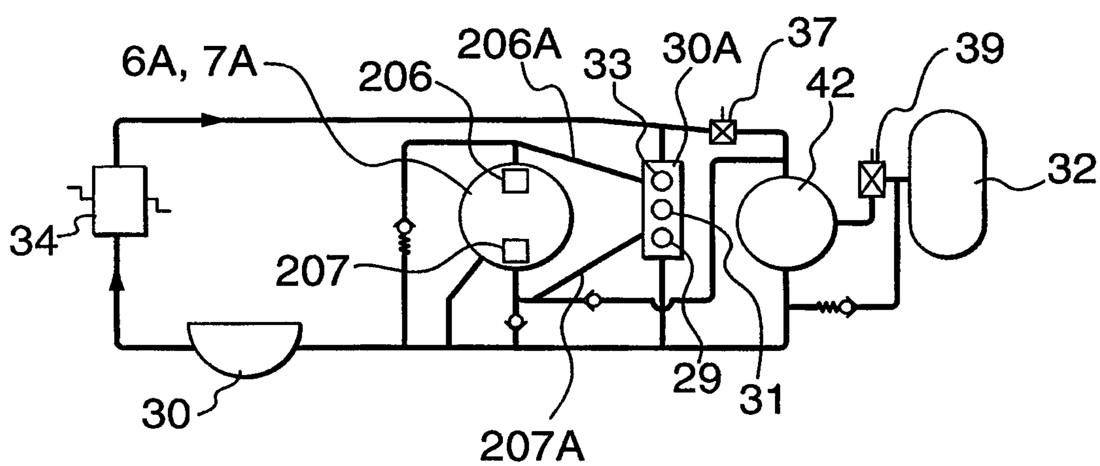

(57) Abstract

A three wheeled lightweight transportation vehicle comprising a human powered hydraulic drive means, a primary and secondary frame, two rear wheel (6, 7) and suspension (14) assemblies and one front wheel (8) and suspension assembly attached to the primary frame, steering means (9) attached to the front wheel (8) and suspension assembly and to the primary frame for controlling the front wheel and suspension assembly, wherein the hydraulic drive means includes pump means (34) for generating pressurized oil and at least one hydraulically powered motor (6a, 7a) adapted to drive at least one of the wheel assemblies.

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LIGHTWEIGHT TRANSPORTATION VEHICLE

Field of Invention

This invention relates to three wheel vehicles with leanable suspension that are hydraulically powered.

Background to the Invention

Three wheeled vehicles are known in the art. One example is the vehicle disclosed in US Patent 4,313,517. In this patent, an electrically powered, three wheeled vehicle is described wherein an electric motor drives the rear wheel assemblies. In order to overcome the instability associated with three wheeled vehicles, heavy batteries are strategically positioned to lower the vehicles' centre of gravity. Power transmission is accomplished by the use of the systems batteries in conjunction with the rear wheel electric motors. The vehicle's braking system includes both mechanical and electro-magnetic brake systems which co-operate together. Electromagnetic braking is accomplished by a short circuiting system which locks the electric motor, causing the vehicle to slow down. Additionally, pedals may be coupled to at least one of the wheels to supply motive power to the vehicle. Finally, the invention features a lightweight canopy which can be removably attached to the existing frame to provide an the occupant with protection from the weather.

This vehicle has several disadvantages. The use of strategically positioned heavy batteries to overcome the stability problem associated with three wheeled vehicles adds additional weight which affects overall vehicle performance. Further, the batteries must be recharged at regular intervals which can be time consuming and inconvenient. As well, the power generated by the manual pedal system cannot be stored for later use nor can the energy expended when braking either mechanically or electro-magnetically. Finally, the absence of

a sophisticated suspension system reduces rider comfort as well as vehicle handling around corners at high speeds.

Hydraulically powered vehicles are also known in the art. For example, US Patent 5,423,560 discloses an hydraulically powered bicycle with a manually actuated pump. At the hub of both the front and rear wheel are positioned vane motors, and a pump assembly is positioned where the crankshaft is located on a conventional bicycle. Forward motion is achieved when pressure is applied to pedal assemblies attached to the pump input shaft. The pressure on the pedal turns the pump and forces fluid through the bicycle tubular frame. The frame serves as a distribution network carrying the hydraulic fluid to the motors. This system has several deficiencies. All bicycles are inherently unstable, relying on the agility of the rider to ensure that the bicycle remains upright while in motion. The bicycle has no suspension means, which is uncomfortable for the rider over rough ground. Finally, there are no means for storing the energy produced by the rider, or for recovering energy under braking.

Chain driven bicycles, both human powered and engine powered are well known, and integrated advanced suspension systems have been used for both the rear and front tire. However, since the ability to lean into a curve is inherent in a bicycle, the suspension systems used have little relevance for a three wheeled vehicle. Further, although a faring serves to protect the rider of a motorcycle to some extent from the weather, ultimately the rider is left exposed.

An example of a full sized hydraulically powered vehicle is disclosed in US Patent 3,966,365, which includes an hydraulic power transmission and braking system for a vehicle such as a passenger automobile. Hydraulic fluid under pressure is

supplied by a variable displacement hydraulic pump which is powered by an internal combustion engine. Fixed displacement hydraulic machines are connected to the both the front and rear wheels. Operator manipulation of fluid flow control mechanisms causes the machines to act as either motors or pumps. In the power transmission mode, high pressure fluid from the variable displacement pump is circulated to the wheel motors to propel the vehicle. A flow regulator determines the rate of fluid flow and thereby the acceleration of the vehicle. Braking is accomplished by creating back pressure on the wheel motors, so that they act as pumps and decelerate the vehicle.

This system also has several disadvantages. The vehicle as a whole is very heavy, and it is relatively large and cumbersome due to the combination of the hydraulic and internal combustion engine components. Further, the braking system is not regenerative, so that the energy used in braking is not stored and recycled. Surplus energy from the variable displacement pump also cannot be stored. Finally, driving the pump with an internal combustion engine adds additional weight, and is environmentally unfriendly.

Summary of the Invention

The present invention seeks to overcome the problems of the prior art by providing a highly efficient three wheeled lightweight transportation vehicle with leanable suspension.

This invention seeks to provide a tricycle vehicle whose power system is a human powered hydraulic propulsion system, combined with integrated front and rear wheel suspension wherein the rear suspension allows the vehicle both to lean into turns and to remain essentially vertical on rough terrain.

In a preferred embodiment of this invention the tricycle is provided with a removable weather protection shield.

Thus in a first broad embodiment this invention seeks to provide a lightweight hydraulically powered vehicle including:

a chassis;

one front and two rear suspension means attached to the chassis for dampening vibrations associated with the movement of the vehicle;

at least two rear wheel assemblies and one front wheel assembly attached to the suspension means;

drive means secured to the chassis for propelling the vehicle;

braking means; and

steering means attached to both the front suspension means and front wheel assembly and the chassis for steering the front wheel assembly;

wherein the drive means comprises in combination:

pump means for generating pressurized oil;

a reservoir hydraulically connected to said pump means for storing unpressurized oil;

at least one hydraulically powered motor adapted to drive at least one of the wheel assemblies;

an accumulator for storing energy in the form of pressurized oil generated by both pump means acting on the oil in the oil reservoir;

pressure transducer means hydraulically connected to the oil reservoir, accumulator, pump means and the motor for preventing significant energy loss during charging and discharging of the accumulator;

control means for regulating the flow of the pressurized oil between the accumulator and at least one wheel assembly; and

clutch means integrated with the motor,

and wherein the rear suspension means comprises inwardly leanable suspension means.

Preferably, the hydraulically powered motors are vane motors.

Preferably, the tricycle further includes a weather protection shell which can be removably attached to the chassis.

Preferably the leanable rear suspension means comprises:

a first hydropneumatic strut means interposed between the first trailing arm and the frame, having an air chamber separated by a flexible diaphragm from an oil cylinder including a piston means, a first valve means included in the piston means constructed and arranged to limit the flow of oil from one side of the piston to the other, and control means for opening and closing the first valve means, interposed between the first rear suspension means and the frame;

a second hydropneumatic strut means interposed between the second trailing arm and the frame, having an air chamber separated by a flexible diaphragm from an oil cylinder including a piston means, a second valve means included in the piston means constructed and arranged to limit the flow of oil from one side of the piston to the other, and control means for opening and closing the second valve means, interposed between the first rear suspension means and the frame;

a balancing pipe connecting together the air chambers of the first and second hydropneumatic strut means;

an air reservoir connected to the balancing pipe by a first and a second air connection;

a one way valve in the first connection constructed and arranged to allow air flow only out of the air reservoir;

and a flow controlling valve in the second connection constructed and arranged to allow air flow at a selected rate into or out of the air reservoir.

The advantages of this vehicle are numerous. By avoiding the use of heavy propulsion systems, the vehicle can be extremely lightweight. The integrated wheel suspension enhances ride comfort by allowing the rider to lean into turns, and by allowing the tricycle to remain essentially upright over surface irregularities. Further, the removable protection shell ensures that the occupant can use the vehicle in a variety of weather conditions.

The regenerative braking system ensures that the energy expended in braking is at least partially recovered for later use when the vehicle is powered. The use of human power to drive the pump simplifies the design and eliminates the need for an auxiliary power source which must be regularly replenished. Finally, the ability of the propulsion system to store energy releases the operator from having to continuously drive the pump, and allows delivery of drive energy much in excess of what the operator could provide.

Brief Description of the Drawings

Preferred embodiments of the invention will be described with reference to the accompanying drawings, wherein:

Figures 1 and 2 are top and side views;

Figures 3, 4, 5 and 6 show three rear suspension systems of the vehicle;

Figure 7 is a schematic diagram of the power transmission and regenerative braking system;

Figure 8 is a cross-sectional view of the wheel motors;

Figure 9 is a cross-sectional view of the wheel motor rotor shown in Figure 8;

Figures 10, 11 and 12 are cross-sectional views of spool valves used to control hydraulic fluid flow;
Figures 13 and 15 are cross-sectional views of the variable displacement treadle pedal piston pump;
Figure 14 is a detail view of part of Figure 13;
Figure 16 is a side view of a slot arm integral to the variable displacement treadle pedal piston pump of Figures 13 and 15;
Figures 17 and 18 are views of the wheel motor clutch;
Figures 19 to 26 show alternative rear suspension systems;
Figure 27 shows detail of one trailing arm mounting arrangement; and
Figures 28, 29 and 30 show a preferred hydropneumatic rear suspension.

For clarity, the rear portion of the tricycle frame is omitted from the Figures; construction of the required supporting elements on the frame follows normal bicycle construction practises.

Description of the Preferred Embodiment

Referring first to Figures 1 and 2, the major components of the hydraulically powered version of the vehicle are shown. Chassis 2 has primary and secondary sub-frames. The primary frame supports the vehicle occupant and all other mechanical and suspension components. The secondary frame supports minor vehicle components, and the weather protection shell 4 which can be removably attached to the secondary frame.

Rear wheel assemblies 6, 7 and front wheel assembly 8 form a triangular vehicle base. The rear wheel assemblies 6, 7 include the propulsion system motors. Front wheel assembly 8 is removably attached to cantilever front forks 13. The forks 13 are connected to the steering mechanism 9 which consists of a steering column 12, linkage 10, and handlebars 11. The

steering mechanism 9 is rotatably attached to chassis 2 by the steering column 12. Rear suspension means 14 are shown connected to rear wheel assemblies 6, 7 and to the chassis 2. Treadle pedals 16 are used by operator 18 to drive a variable displacement pump. The hydraulic drive system is described in more detail below.

Figures 3, 4, 5 and 6 show leanable suspension means. In these suspensions, an equalizing means is used in conjunction with suspension members to eliminate imparting roll torque along the longitudinal axis of the frame, particularly when cornering at speed. The suspension is arranged such that when one of the rear wheel assemblies 6,7 moves upwardly relative to the axis of the chassis 2, the other rear wheel assembly can move. This has two consequences. When cornering, it allows the tricycle to lean, as indicated by the angle α in Figure 3. When negotiating an irregular surface it allows the tricycle to remain substantially vertical, as indicated by the surface A shown in chain line in Figure 3. These two circumstance can also be combined, thus providing the operator with significantly improved control of the tricycle.

In the configuration of Figure 3, crossbeam 20 is pivotally attached at its centre point 21 to frame 2, shown chain dotted. Extending substantially vertically downwards from the ends of crossbeam 20 are combined spring and shock absorber struts 22, 23. The bottom ends of struts 22, 23 are connected to trailing arms 19. The front ends of each trailing arm is pivotally connected to the chassis, and the rear ends carry the rear wheel assemblies 6, 7. The coordinated movement of the beam 20 and the trailing arms 19 ensures that the tricycle can be controlled, enhancing vehicle stability and leanability.

Figures 4 and 5 outline a further embodiment of the rear suspension of the proposed hydraulic vehicle. In this forward cross beam system, a horizontally positioned crossbeam 15 is pivotally connected to chassis 2 at point 17. A pair of struts 22, 23 extend substantially horizontally rearward from crossbeam 15 and pivotally attach to L-shaped trailing arms 25, 26 which carry rear wheel assemblies 6, 7. The elbows of L-shaped trailing arms 25, 26 are pivotally connected to the frame 2 at points 27, 28 (only point 28 is shown in figure 4). This system operates in the same fashion as that in Figure 3, and has the advantage of requiring less space in the vehicle. It also transmits the suspension loads directly into the main chassis frame 2 of the tricycle. A variation on the system of Figure 3 is shown in Figure 6. This is shown arranged vertically; it can also be used horizontally as shown in Figure 5. In this system the struts 22,23 are replaced by rigid members 22A, 23A. A single strut 24 is used to provide springing, which is located between the pivot point 21 in the crossbeam and its mounting to the chassis at 21A.

Figure 7 shows a schematic layout respectively of the hydraulic system. A manually actuatable piston pump 34, in co-operation with oil reservoir 30 provides pressurized oil. The manually actuatable pump can be either fixed or variable displacement and can be operated using either a treadle pedal or a standard pedal and crankshaft mechanism. By varying the displacement in the variable displacement option, the operator can vary the pedalling effort along with the cycle rate of the pump. The low pressure oil reservoir 30 is required because the volume of the accumulator 32, which will be described later, can change by up to four litres during the charge and discharge cycles. The oil reservoir 30 is a conventional tank that stores unpressurized oil. In a preferred embodiment, the oil reservoir 30 is approximately 4 liters in size, and includes an air

chamber, a diaphragm and an oil chamber wherein the diaphragm will either expand or contract depending on the volume of oil in the tank. This structure is designed to keep air and dirt out of the system and also serves as a pressure equalizer, so that changes of oil level due to hydraulic system draw or the ambient atmospheric condition changes will not cause any significant pressure differential across moving seals such as those found on pump 34.

Pump 34 connects to pressure regulator 42 which in turn connects to accumulator 32. The most important function of pressure regulator 42 is to prevent significant energy loss during the charging and discharging cycles of the accumulator 32. The pressure regulator 42 is a compact single armature device with two chambers which can allow any pressure and flow of supplied or delivered oil to or from the accumulator 32. This serves to maintain a high conversion efficiency. The accumulator 32 stores energy in the form of pressurized oil. Like the oil reservoir, the internal structure comprises an air chamber, a diaphragm and an oil chamber. Pump 34 drives oil into either or both the wheel motors 6A, 7A, or the accumulator 32 causing the internal diaphragm to expand and compress the air held in the air chamber to create a pressure differential between the air chamber and oil chamber. When pressurized oil is required at the rear wheel hydraulic motors 106, 107, the pressurized air drives the oil out of the accumulator 32 through the hydraulic pressure transducer 42 to the wheel motor control valve. Through the manipulation of control valves 29, 31, 33, 37, and 39 the flow of hydraulic fluid to the various components of the system can be controlled. For example, if the rider wishes to stop fluid flow to the accumulator 32 so that all fluid is directed to the rear wheel motors 6A, 7A then control valve 37 would be closed. The relief valves shown solid in Figure 7 return oil to reservoir

30 in the event of over pressurization in the system. In this system, control of the various valves is conveniently incorporated into two hand grips 36, 38 (see Figures 1 and 2), which will also include integral brake levers. In a preferred embodiment, handgrip 38 controls forward acceleration, detent centre and regenerative braking, and handgrip 36 controls pedal pump displacement. The fixed displacement wheel motors have a bi-directional clutch (described below) designed to disengage the armature from the wheel shaft, thereby allowing the vehicle to coast with little friction. When handgrip 38 is placed in the regenerative braking position, operation of pump 34 can be used to charge the accumulator while the vehicle is stationary. Turning handgrip 38 to the forward acceleration position will connect accumulator 32 to the wheel motors 6A, 7A causing the vehicle to move forward. Sustained operation of pump 34 will continue to provide hydraulic fluid to the accumulator and to the wheel motors as desired.

Braking is accomplished through both primary and secondary systems. The primary system is a regenerative braking system while the secondary system is a conventional mechanical braking system such as internally expanding drum brakes actuated by hand brake levers included with the handgrips 36, 38. The regenerative braking system uses the motors 106, 107 as pumps during the deceleration phase. By setting the valves so that the motors 6A, 7A to pump the pressurized oil in the hydraulic system, the rotation of the motor is continuously resisted, thereby causing the vehicle to slow down or even stop. The oil pumped by the motors is directed to accumulator 32 so that the kinetic energy of the moving vehicle is translated into stored energy in the form of pressurized oil. The fluid flow required to accommodate regenerative braking is managed by reversing the in and out ports of the wheel motors 6A, 7A using valves 29, 31, 33. Oil flow is thereby directed to pressure transducer 42.

Depending on how much operator 18 turns handgrip 38, more or less pressure can be placed on the wheel motors.

A preferred wheel motor construction for the motors 6A, 7A is shown in Figure 8. The main shaft 53 is preferably stainless steel, to ensure that the oil seal 54 is not damaged by shaft corrosion. Clutch pack 44 enables disconnection of the motor to allow near frictionless coasting. Steel cam ring 45 houses rotor 49 which rides on torque tube 48. This arrangement completely isolates rotor 49 from forces arising from shaft 53 moving during cornering loads. Shaft 53 rotates freely on ball bearings 46 and roller bearing 50. Ball bearing 46 also serves to counteract thrust on shaft 53. Wheel bolt hole 52 allows for easy engagement and disengagement of a rear wheel (not shown). This single bolt arrangement is also used to secure the front wheel on the axle included in cantilever arm 13. The single bolt arrangement could be replaced by other well known means for securing the front and rear wheel assemblies. The motor is completed by end plates 55, 56 between which the steel cam ring 45 is fastened. End plates 55, 56 are preferably aluminum to reduce weight.

Figure 9 provides a more detailed view of wheel motor rotor 49 positioned inside steel cam ring 45. Through crowned spline 58, rotor 49 is connected to the torque tube 48 which in turn rides in a hole through end plates 55 and 56, and due to sufficient clearance avoids contact with the main shaft 53. The rotor 49 includes a plurality of slots 57 occupied by pressure balanced dual vanes 60. The steel cam ring 45 is provided with constant radius sections, so that vane slot losses due to friction are eliminated by the constant radius sections in areas where the vanes have a differential pressure across them.

Figure 10 illustrates the operation of valve 30A of Figure 7. Figure 11 is a schematic diagram of the valve 37 of Figure 7. Referring to Figure 7, it will be noted that the wheel motors are shown with ports 206 and 207 which are connected to 206A and 207A of valve 30A. As illustrated, the valve also includes ports 29, 31, 33, and 35 and a connection leading to the reservoir 30. The valve is shown in the rest or motor position. When the valve moves from the rest position to the non-rest position it redirects the motor port 206A from port 31 to port 29 and blocks off 207A motor port from port 33. The 207A motor port can still exit to port 35 through a check valve. Similarly with valve 37 of Figure 11, the valve is shown in the open position, not the rest position and moving the spool to the rest position blocks the pedal pump port PUMP from the motor circuit.

In both Figures 10 and 11, R indicates a drain connection to reservoir 30.

Figure 12 details the control valve labelled as 39 in figure 6. This control valve is a pilot operated valve that has three purposes: first, it prevents accumulator leak down; second, it prevents unintended reverse operation of the vehicle; and third, it prevents accidental over speed of the wheel motors when they are in the free wheel mode. The valve 39 includes port A connected to the accumulator and a port B connected to the wheel motor and pedal pump circuit. Piston 79 is composed of a head portion 80 and a rod portion 88. Piston 79 is slidably received into housing 82. At the base of head portion 80 is seated O-ring 84 designed to inhibit fluid flow when the control valve is in the closed position (shown). Wound around rod portion 88 is spring 86.In operation, the valve has four possible conditions as follows:

1. The vehicle is stopped, the accumulator is charged and the brake signal is effected.

There is no pilot operation; valve 39 remains closed.

2. The vehicle is stopped or moving, the accumulator is charged.

A set of pilot valves (not shown) makes use of the higher pressure of accumulator 32 compared to port B to cause valve 39 to open rapidly (i.e. head portion 80 slides into housing 82). The action occurs with the operator's forward acceleration signal.

3. Vehicle coasting, some accumulator charge, operator signals regenerative braking.

There is no a pilot valve signal, but instead pressure build-up at port B forces valve 39 open. Once open, the valve remains open unless signalled to close, and only if the pressure at A and B is at least 600 psi above the pressure of reservoir 30.

4. System Discharged.

Spring 86 will open valve 39 readying the vehicle for pedalling via port A or regenerative braking via port B.

Figure 13 shows a cross-sectional side view of a one cylinder variable displacement treadle pedal piston pump that operator 18 acts upon to propel the vehicle and charge accumulator 32. Drive arc 91 is pivotally connected to chassis 2 at point 90. Foot 92 is seated against drive arc 91. Movement of foot 92 relative to drive arc 91 is restricted by co-operating interlocking teeth integral to the bottom surfaces of drive arc 91 and foot 92 (see Figure 14). Connecting rod 93 extends between foot 92 and piston 96 and is linked by pins 94 and 99 respectively. Piston 96 is seated in cylinder 98, the base of which houses spring 97. When drive arc 91 is rotated about point 90, it drives con rod 93 forward which in turn moves piston 96 down cylinder 98 and compresses spring 97. Piston 96

is returned to its' rest position (shown) by the expansion of spring 97. The cycling of piston 96 moves oil through cylinder 98. The oil enters and leaves cylinder 98 by self actuating check valves. Drive arc 91 and foot 92 have the same centre of curvature at pin 94.

Slotted arms 100 and 101 which rotate about pin 102 (see Figures 15 and 16), serve to hold base 92 in a given position and limit the travel of piston 96. Slotted arms 100, 101 ensure that when the piston is in its rest position, a small gap is present between the interlocking teeth of drive arc 91 and foot 92 (see Figure 14). If operator 18 wants to change the displacement of the pump 34, then foot 92 is moved to a different position on drive arc 91. Movement of slotted arms 100, 101 and in turn foot 92 can be accomplished by a cable extended to a control mechanism (not shown) on handgrip 36.

Pin 94 could be replaced by a ball and socket joint which is more typical in hydraulic design. The travel of piston 96 can be limited by a piston stop in the end of cylinder 98. The variable displacement treadle pedal piston pump can also be replaced by a standard pedal assembly and a fixed displacement pump or with a two cylinder variable displacement treadle pedal piston pump. The latter requires that each pedal be connected to an individual treadle pedal which would co-operate with a piston associated with one of the two cylinders. This would necessitate the use of a mechanism, such as a chain or linkage, interconnecting the treadle pedals to ensure equal and opposite pedal movement.

Operation of the bi-directional clutch 44 in Figure 8 will now be explained with reference to Figures 17 and 18. In order to explain the operation of the bi-directional clutch, it is shown for simplicity sake as a linear arrangement in Figure 17 rather

than as a circular arrangement. A grooved roller 103 occupies most of the pockets 104 in race 105. Springs 106, in slots 107, push the rollers 103 to the centre bottom of pockets 104. This action moves retainer 108 to the position shown in Figure 18. Ratchet pawl 109 is attached to retainer 108 by a slot 110 and is pushed in the direction of arrow 17A in the slot by springs (not shown). In the "passive" direction, the pawl 109 is spring loaded to enter pockets 111 in race 112 as race 112 travels in the direction of arrow 17B. During regenerative braking, another pocket 104 contains another pawl (not shown) which points in the direction of arrow 17B. Means are also provided for raising the pawl manually, so that regenerative braking can be disabled if not required. The regenerative braking pawl should not be raisable while under load, but a brief motor direction pulse will cause it to release. If the race 112 moves in the direction of arrow 17B, pawl 109 will engage pocket 111 and cause retainer 108 to move in the same direction. The slot spring for pawl 109 is strong enough to override all the roller springs 106 at once. This action also moves rollers 103 in the direction of arrow 17B, and out into pockets 111 and 104. Roller pin slots in retainer 108 permit this. The rollers 103 engage pockets 111 and 104 simultaneously transmitting the load. Pawl slot 110 and springs (not shown) prevent any significant load from being transmitted by pawl 109. Similarly, when the reverse pawl is lowered the clutch will engage in the opposite direction. The groove in rollers 103 could be eliminated by providing a second spring slot in race 112.

This clutch has several benefits. First, the rollers 103 have a large load carrying capacity. This, combined with a light engagement pawl 109, means that the clutch can be small as well as having a small coasting friction. Second, the clutch is made of simple parts. Third, since the wheel rpm of the tricycle wheels is relatively low, the small size of the clutch permits

engagement of regenerative braking without damage to the clutch.

The chassis parts, and the primary and secondary frames, conveniently are constructed from welded mild steel, chromoly tubing, silver brazed lightweight tubing, fibre reinforced plastic or the like. In the preferred embodiment, the primary frame is a triangulated tube design providing maximum rigidity and minimum weight.

The preferred hydraulic fluids are either power steering or automatic transmission fluid, although other fluids are suitable.

The front suspension system incorporates a conventional design in which a shock absorber is integrated into the cantilever arm 13. Alternatively a standard bicycle fork can be used, either with our without resilient suspension means.

In Figures 19 - 26 alternative rear suspension systems are shown.

A cable based system is shown in Figures 19 and 20. Two cranked trailing arms 191, 192 are connected by the cable 190 which passes around the pulleys 193, 194, which are supported by a cable frame 195. The cable frame 195 is supported on the tricycle frame, and moves against a combined spring and shock absorber strut 196. Net vertical movement of both wheel is controlled by the strut 196, and the ability of wheels to move relatively is provided by the cable 190 moving around the pulleys 193, 194.

Figures 21, 22, and 23 show a group of suspension systems analogous to the earlier Figures in which a fluid based system

is used to provide the equalisation function. Thus such systems can utilise pneumatic, hydropneumatic, or hydraulic components for both the springing and leaning functions.

Figures 21 and 22 are similar to Figures 3 and 4. In Figure 21, which is a rear view, the struts and cross beam of Figure 3 are replaced by two pneumatic, or hydropneumatic, struts 210, 211, which are connected together by the pipe 213. Although air can flow freely through pipe 213, the overall air pressure in the system is controlled by the regulation unit 214. In Figure 22, which is a side view, the arrangement shown in Figure 4 is similarly revised, using two pneumatic, or hydropneumatic, struts 210 (only one is shown) linked by a pipe 213; the air pressure is controlled by the regulator 214. In both of these arrangements, each wheel can respond to irregularities, and both can move in opposite directions by air transfer between the units to allow the tricycle to lean into a corner. The regulation unit controls the effective spring rate of the units.

The arrangement shown in Figure 21 can be modified if instead of hydropneumatic struts, double acting hydraulic cylinders are used for 210 and 211. With a double acting cylinder, both chambers can be connected together, the upper ones by the pipe 213, and the lower ones by the pipe 221, shown ghosted. The pipe 221 also includes a similar reservoir 224, and both of the pipes 213, 221 are provided with shut off valves 223, 224, 225 and 226. The regulator 214 is also replaced by an air over oil pressurised unit. This system functions as follows.

The upper ends of the cylinders 210, 211 together with the air pressurised reservoir provide the suspension functions; the effective springing rate being determined by the air pressure in the reservoir. The lower ends of the cylinders 210, 211

provide the leaning function, by allowing oil to flow through the pipe 221 between them. The reservoir 222 has no effect on this flow, as it is not pressurised. The four shut off valves 223, 224, 225 and 226 control fluid flow between the two cylinders. When the tricycle is being ridden under normal circumstances they are open. When these valves are closed there is no fluid movement into and out of the two cylinders 210, 211, and the suspension is locked and cannot move. This has several uses. It makes the tricycle more manouverable at low speeds. It facilitates keeping the tricycle vertical when stopped. It also acts as an anti-theft device: the valves can easily be controlled by a key, thus allowing the rider to lock the suspension with the rear wheels out of vertical. The tricycle can then only be ridden in a circle.

The arrangement shown in Figure 23 is related to both of Figures 21 and 22. A simple trailing arm 233 is used as in Figure 4, attached to a frame mounted pivot means 235. A rotary multiple vane pneumatic unit 236 is mounted between the trailing arm 233 and the frame, to control the movement of the wheel assembly. The other trailing arm is similarly mounted. As before the two rotary units are interconnected by the pipe 233, and the air pressure is controlled by the regulator 234.

Figures 24 and 25 show an alternative mechanical arrangement, in which a gear differential unit is used. The two trailing arms 243, 244 are each mounted onto shafts 250, 251, which are carried on suitable mounts on the frame (not shown). The shafts are each connected to a gear in the differential, and these gears are interconnected by a pair of gears carried by a spider, which is attached to the gear case 252. Movement of the gear case is controlled by at least one strut 253, and desirably two struts 253,254, attached to mounting points on the frame. As shown in Figure 17, strut 253 is located

rearwards, and strut 254 is located forwards. If desired, both struts can be in the forward direction, thus saving some space. In response to irregularities, either or both wheels move and cause the carrier to rotate against the struts. When the vehicle is leaned into a corner, the shafts 251, 252 rotate relative to each other, thus providing the required leaning function.

In Figure 26 is shown schematically a simpler unsprung system, related to Figure 3. To the rear of the frame 260 is attached a bearer 261 which carries a support 262 with a pivot 263 at its end. Attached to the pivot 263 is an equalising beam 264. The beam 264 is thus able to rotate through a limited arc about the pivot 263. At each end of the beam 264 a pair of connecting links 21A, 22A are pivotally attached at their upper ends to the beam 264 and at their lower ends to the two trailing arms 19. The two trailing arms are carried by the pivots 265, 266 on a cross bar 267 which is rigidly attached to the rear end of the frame 260. The two trailing arms 19 can each rotate vertically through a limited arc. As this system does not include any springing means, the two trailing arms 19 cannot move together in the same direction. As shown by the pairs of arrows X, Y if one arm moves upwards, the other has to move downwards, thus allowing the tricycle to lean into a curve, and to negotiate uneven ground. Thus the integration of the pivoting beam 264 into the suspension system serves to eliminate the imparting of roll torque to the frame by forces arising when uneven ground is encountered or when the vehicle rounds a curve sharply.

In the preceding description, the mounting means whereby the front end of each trailing arm is attached to the frame are spaced apart, more or less at the spacing required to obtain the desired track for the rear wheels. For a single person

tricycle this will typically be of the order of 45cm to 50cm, so that the tricycle needs little more space, if any, than a conventional bicycle. This has the advantages that the trailing arms are substantially straight, and are not subjected to significant torsional stresses as the suspension moves. Additionally, a cross beam, if used as shown in these Figures, is of a reasonable length. If desired, as shown schematically in Figure 27, the mounting pivots 271, 272 may be located close together onto the rear end of the frame 283, and cranked trailing arms 284, 285 used to obtain the desired track.

A preferred hydropneumatic suspension system which can be used with several of the suspensions described above is shown in Figure 28, and details of the valving arrangement used are shown in Figures 29 and 30.

Each hydropneumatic unit is attached at one end 290 to a trailing arm, and at the other end 291 to the tricycle frame. Conventional rubber bushed mountings, as shown schematically at 290, are used at both ends. The cylinder 292 contains a piston 293 attached to the tube 294. A suitable seal, not shown, is also provided between the piston 293 and the inside of the cylinder 292. The upper end of the cylinder is sealed by the flexible diaphragm 295 attached at one end to the end of the cylinder at 292A and at the other end to the support plate 296. A second flexible diaphragm 297 is attached at one end also to the cylinder at 292A, at its other end 298 to the casing 299. Both of these diaphragms are of the so-called "rolling sock" type. A bearing 300 for the tube 294 is also provided at the end 292A of the cylinder which contains a suitable seal (not shown). It can thus be seen that as the two ends 290, 291 move relative to each other the piston 293 slides within the cylinder, and the tube 294 slides within the bearing

300. The spaces 301,302,303 and 304 all contain oil, and the space 305 contains air.

The piston 293 is provided with at least two bores 306, 307 which communicate with the space 304 within the tube 294. Within the tube 294 and inside the piston 293 is a valve 308, the details of which are discussed below. The valve 308 is operated by the rotatable control rod 309, which passes through the oil seal 310. Control rod 309 does not move when the ends 290,291 of the strut move relative to each other, as it is attached at its lower end to the valve 308 within the piston 293. The air space 305 is connected by pipe 311 to the strut on the other side of the tricycle(not shown). Air flows freely through pipe 311 between the two linked air spaces. An air reservoir 312 is connected to the air pipe 311 by two connecting pipes 313, 314. Pipe 313 includes a control valve 315, and pipe 314 includes a one-way valve 316, which is set to allow air flow only out of the reservoir 312.

The valve 308 is shown in Figure 29 in the closed position.

The piston 293 has bores 306 and 307 along with a pin 580 facing inward.

The tube 294 is not connected to the valve body 400. The valve body 400 is rotatably housed within the piston 293. The valve body 400 is a tube open at both ends. The valve body 400 contains a pair of rollers 510, at least one upper hole 520, at least one lower hole 530, a pair of springs 540, and a pair of stoppers 550. Also, the inner face of the valve body 400 has two pairs of ridges 560. Each roller 510 is captive between a pair of ridges 560. Each upper hole 520 is in communication with a corresponding lower hole 530. For every pair of ridges 560, one ridge has adjacent a spring 540 while

another has adjacent a stopper 550 and a roller 510 in between a ridge pair 560. The upper hole 520 is above the lower hole 530. The holes 520, 530 are between a stopper 550 and a spring 540. The outside of the valve body 400 has a slot 570. Captive in this slot 570 is the pin 580 on the inner face of the piston 293. The slot 570 is long enough to only allow the valve body 400 to rotate within a certain distance.

The control rod 309 enters the piston 293 through the open end and enters the lower tube 294 through its corresponding open end. The end of the control rod 309 has a pair of detents 600. Each detent 600 is in contact with a roller 510. Each detent 600 is also shaped to engage a stopper 550. The control rod 309 is free to rotate within the valve body 400.

The workings of the valve 308 will now be examined. The valve 308 has two positions, locked and unlocked. In the unlocked position, the upper pair of connecting holes 520 are aligned with the bores 306 on the piston 293 and the lower pair of connecting holes 530 are aligned with the bores 307 on the piston 293. In the unlocked position, oil can freely travel from the space 301 to the space 302 through holes 520 and 530 and through bores 306 and 307. In the locked position, the upper hole 520 is not aligned with the bore 306 on the piston 293 and the lower hole 530 is not aligned with the bore 307 on the piston 293. This effectively stops oil from flowing from space 301 to space 302.

The locking function is accomplished by rotating the valve body 400. To explain the workings of the locking function, the following description will only take into account one side of the valve body 400. It must be understood that the other side of the valve body 400 functions in a similar manner. When in the unlocked position, the spring 540 is extended and pushes

the roller 510 against the ridge 560 adjacent the stopper 550. At this point the detent 600 at the bottom of the control rod 309 is engaging the stopper 550. To lock the mechanism, the control rod 309 is rotated clockwise, carrying with it valve body 400 until the pin 580 encounters the end of the slot 570. This removes the alignment between the connecting holes 520, 530 and bores 306, 307. Continued rotation of rod 309 causes roller 510 to be squeezed against the inner wall of valve body 400 due to detent shape 600 and this causes the valve body 400 to deform and expand outwardly. The friction between the outer face of the valve body 400 and the inner face of the piston 293 prevents rotation of valve body 400, while detent shape 600 locks the valve mechanism.

To unlock the valve 308, the control rod 309 is rotated counterclockwise. By doing so, the roller 510 is moved away from the spring 540. The spring 540 assists in this as it is compressed. By the time the roller 510 is in contact with the other ridge 560, the detent 600 is in contact with the stopper 550. At this point the valve body 400 is no longer deformed and is no longer locked. Further rotation of the control rod 309 causes the valve body 400 to rotate as well. However, this rotation is not uncontrolled as the pin 580 reaches the end of slot 570, thereby preventing further rotation. The pin 580, when it reaches the end of the slot 570 in the unlocked position, aligns the connecting holes 520, 530 and the bores 306, 307. This allows the free flow of oil between spaces 301 and 302.

This suspension system can function in two separate modes, which are unlocked, and locked.

During unlocked operation, valve 308 in piston 293 is open, and piston 293 is free to move; oil can flow between spaces 301 and

302, and any volume change in the space 304 is accommodated by the orifice 317. If one strut is moved upwardly, for example due to a surface irregularity, or if the tricycle is leaned, air flows through connection 311, thus maintaining constant air pressure in both struts and air chamber 312. A shock absorber function is provided by the valves 315 and 316. When the pressure in the reservoir 312 is higher than that in the pipe 311, valve 316 opens, and the pressures equalise. When the pressure in pipe 311 is higher than that in the reservoir air flows though valve 315 until the pressures again equalise; the setting of valve 315 controls the air flow, and thus the rate at which the pressures are equalised.

During locked operation, the valves 308 are closed. This seals both spaces 301 and 302, and prevents oil flow between spaces 301,302, and 304. When locked, the trailing arms cannot move, and the ability to respond to an irregular surface and to lean is lost.

It must be noted that the air chamber 312 with the attendant connecting pipes 313, 314 and the valves 315 and 316 can be omitted without affecting the vehicle's ability to lean or its ability to respond to irregular surfaces. However, omission of this sub-system will remove the shock absorbing function.

In this arrangement, the oil is present only as a lubricant and to enable the locking function. The air chambers provide both springing and shock absorber functions, and allow reaction to irregular surfaces and leaning.

In the preceding description, the embodiment described is a trailing arm system. For a number of reasons, this is the preferred arrangement. It permits the use of many conventional bicycle parts, is light and compact, is well adapted to locate

both rear wheels reliably, and accommodates the loads imposed when the tricycle is ridden. However, it is understood that other suspension means, which may or may not incorporate a springing function, can also be used, such as a sliding pillar arrangement. The trailing arm itself can also be modified, for example as a twin arm similar to a bicycle front fork, and as a trailing A-frame.

The rear suspension of this invention in addition to providing the option of a more comfortable ride, improves the handling of the tricycle, by allowing it to lean into corners at speed, and to negotiate broken ground in a more or less vertical position.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A lightweight hydraulically powered vehicle including:

a chassis;

one front and two rear suspension means attached to the chassis for dampening vibrations associated with the movement of the vehicle;

at least two rear wheel assemblies and one front wheel assembly attached to the suspension means;

drive means secured to the chassis for propelling the vehicle;

braking means; and

steering means attached to both the front suspension means and front wheel assembly and the chassis for steering the front wheel assembly;

wherein the drive means comprises in combination:

pump means for generating pressurized oil;

a reservoir hydraulically connected to said pump means for storing unpressurized oil;

at least one hydraulically powered motor adapted to drive at least one of the wheel assemblies;

an accumulator for storing energy in the form of pressurized oil generated by both pump means acting on the oil in the oil reservoir;

pressure transducer means hydraulically connected to the oil reservoir, accumulator, pump means and the motor for preventing significant energy loss during charging and discharging of the accumulator;

control means for regulating the flow of the pressurized oil between the accumulator and at least one wheel assembly; and

clutch means integrated with the motor,

and wherein the rear suspension means comprises inwardly leanable suspension means.

2. The hydraulically powered vehicle of Claim 1 wherein the hydraulically powered motor is a vane motor.

3. The hydraulically powered vehicle of Claim 1 wherein the chassis comprises a primary and secondary frame.

4. The hydraulically powered vehicle of Claim 3 which further includes a weather protection shell removably attached to the secondary frame.

5. The hydraulically powered vehicle of Claim 1 wherein the clutch means comprises a bi-directional wheel motor clutch having a first and second position, wherein the first position causes the motor to disengage from the wheel assembly and the second position causes the motor to engage the wheel assembly.

6. The hydraulically powered vehicle of Claim 1 wherein the pump means is taken from the group consisting of human powered fixed displacement treadle pedal piston pumps, human powered fixed displacement pedal and crankshaft piston pumps, human powered variable displacement treadle pedal piston pumps, human powered vane and gear pumps, solar powered pumps, internal combustion engine powered pumps, battery powered pumps, and fuel cell powered pumps.

7. The hydraulically powered vehicle of Claim 1 wherein the steering means comprises handle bars rigidly mounted to a steering column which is rotatably linked to a cantilever axle which receives the front wheel assembly.

8. The hydraulically powered vehicle of Claim 1 wherein the braking means comprises a primary and a secondary braking system, the primary braking system comprising a regenerative braking system comprising valve means integrated with the drive means wherein the motor is used as a pump to transfer the kinetic energy generated by the vehicle to the accumulator when the valve means are adjusted to permit fluid to flow from the motor to said accumulator and wherein the degree of braking is controlled by adjusting the pressure on the motors using the valve means; and the secondary braking system comprising brake drums, discs or calipers mounted on the rear and front wheel assemblies.

9. The hydraulically powered vehicle of Claim 7 wherein the braking means comprises a primary and a secondary braking system, the primary braking system comprising a regenerative braking system comprising valve means integrated with the drive means wherein the motor is used as a pump to transfer the kinetic energy generated by the vehicle to the accumulator when the valve means are adjusted to permit fluid to flow from the motor to said accumulator and wherein the degree of braking is controlled by adjusting the pressure on the motors using the valve means; and the secondary braking system comprising brake drums, discs or calipers mounted on the rear and front wheel assemblies and which are actuated by hand brake levers mounted on the handlebars.

10. The hydraulically powered vehicle of Claim 1 wherein the primary and secondary frames are taken from the group consisting of welded mild steel, chromoly tubing, silver brazed lightweight tubing or reinforced plastic fibre.

11. The hydraulically powered vehicle of Claim 1 wherein the leanable suspension means comprises: a crossbeam, the centre

of which is pivotally connected to the frame; a pair of struts with first and second ends; and two trailing arms with first and second ends, wherein the first ends of the struts are pivotally connected to opposing ends of the crossbeam and the second ends are vertically mounted to the trailing arms, and wherein the first ends of the trailing arms are pivotally attached to the frame and the second ends are removably attached to the rear wheel assemblies.

12. The hydraulically powered vehicle of Claim 1 wherein the leanable suspension means comprises a forward cross beam system comprising: a horizontally positioned crossbeam, the centre of which is pivotally connected to the frame; a pair of struts with first and second ends; a pair of L-shaped trailing arms with first and second ends, wherein the first ends of the struts are secured to opposite ends of the crossbeam, and wherein the first ends of the L-shaped trailing arms are pivotally connected to the second ends of the shock absorbers and the second ends of the trailing arms are removably attached to the rear wheel assemblies, and wherein the elbows of the L-shaped arms are pivotally connected to the frame.

13. The hydraulically powered vehicle of Claim 1 wherein the leanable rear suspension control means comprises:

a first hydropneumatic strut means interposed between the first trailing arm and the frame, having an air chamber separated by a flexible diaphragm from an oil cylinder including a piston means, a first valve means included in the piston means constructed and arranged to limit the flow of oil from one side of the piston to the other, and control means for opening and closing the first valve means, interposed between the first rear suspension means and the frame;

a second hydropneumatic strut means interposed between the second trailing arm and the frame, having an air chamber separated by a flexible diaphragm from an oil cylinder including a piston means, a second valve means included in the piston means constructed and arranged to limit the flow of oil from one side of the piston to the other, and control means for opening and closing the second valve means, interposed between the first rear suspension means and the frame;

a balancing pipe connecting together the air chambers of the first and second hydropneumatic strut means;

an air reservoir connected to the balancing pipe by a first and a second air connection;

a one way valve in the first connection constructed and arranged to allow air flow only out of the air reservoir;

and a flow controlling valve in the second connection constructed and arranged to allow air flow at a selected rate into or out of the air reservoir.

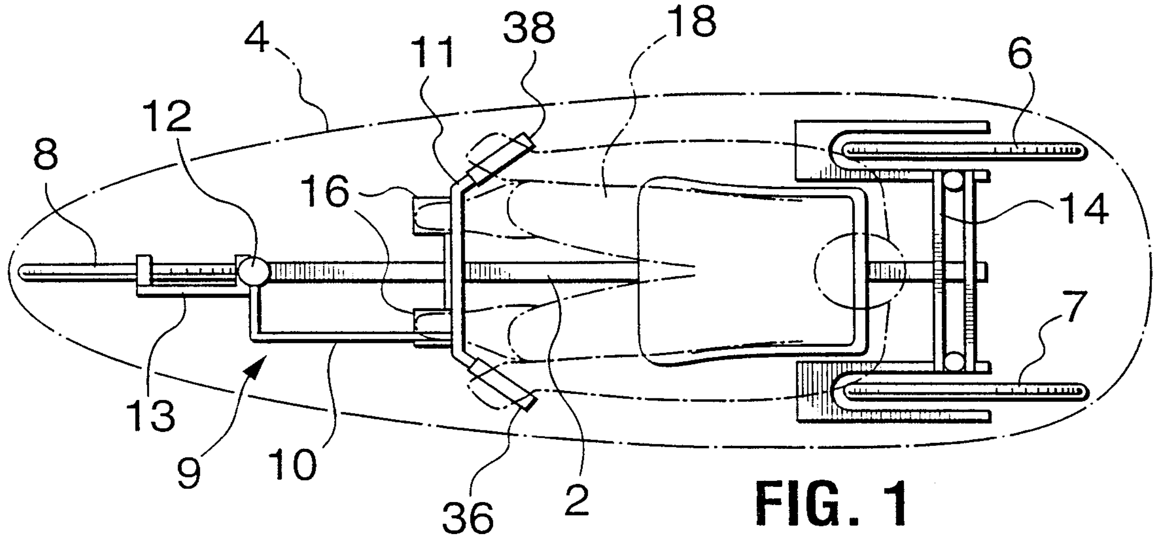


FIG. 1

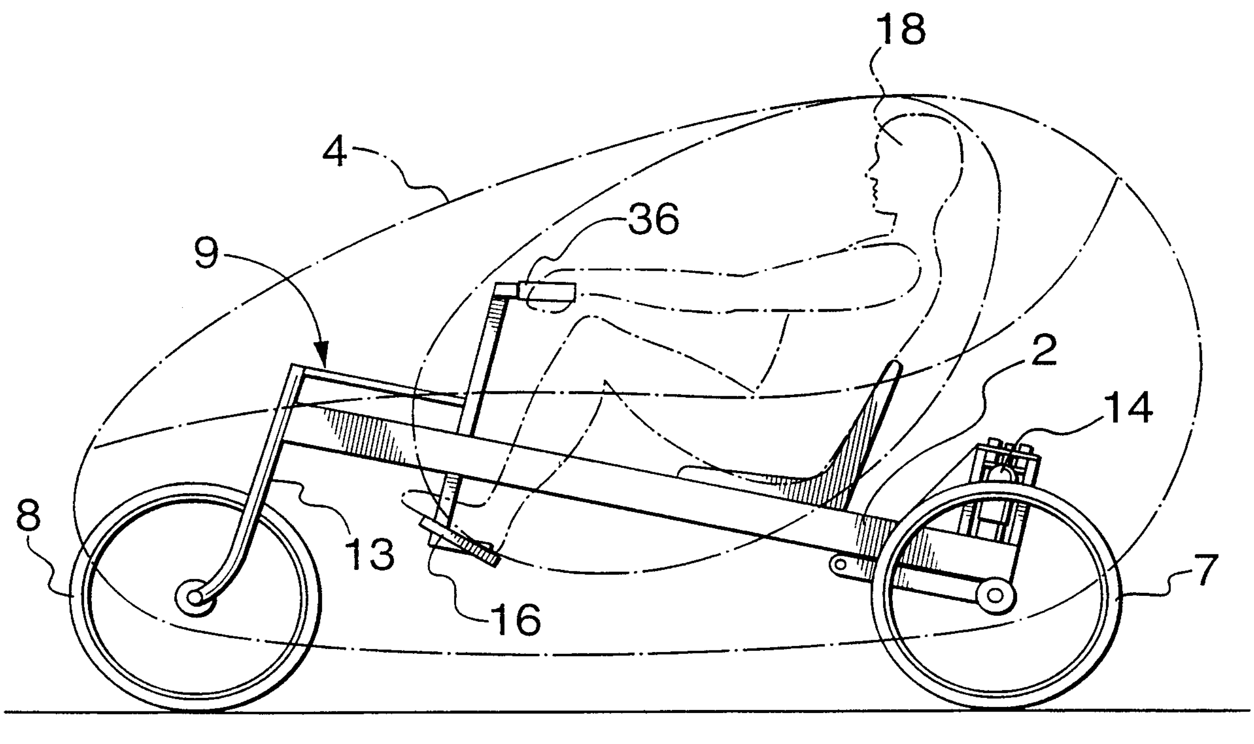


FIG. 2

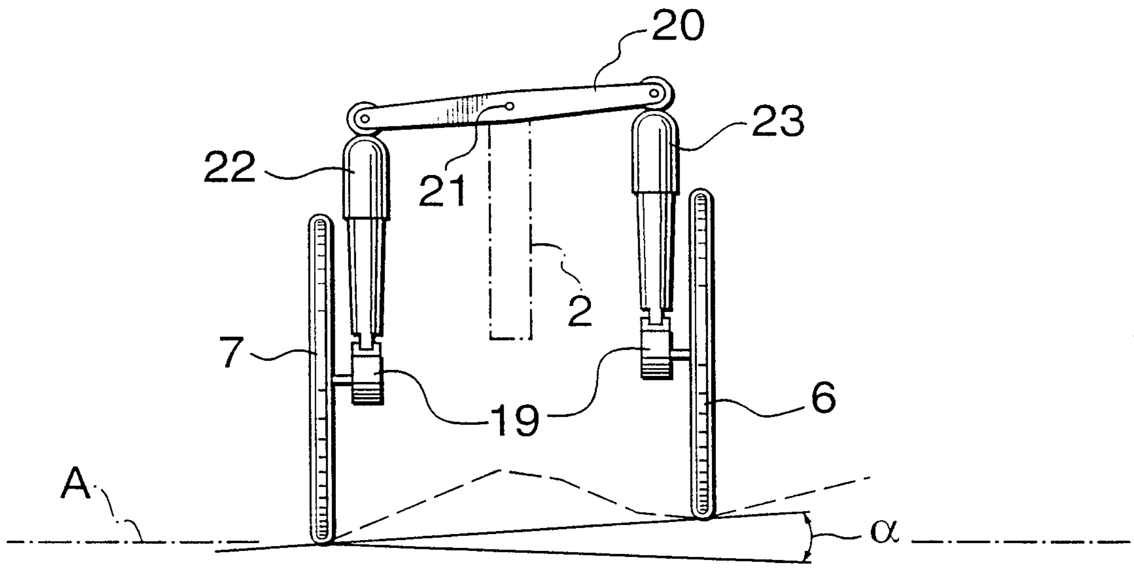


FIG. 3

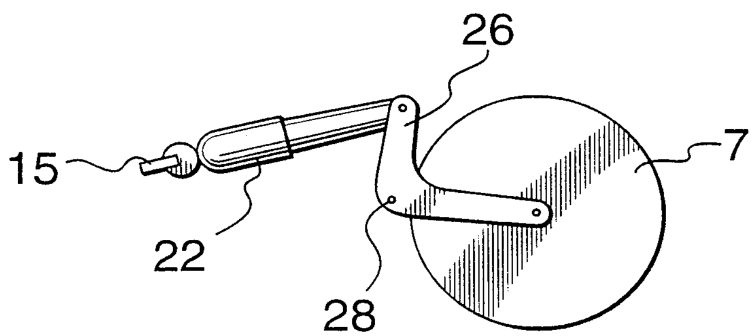


FIG. 4

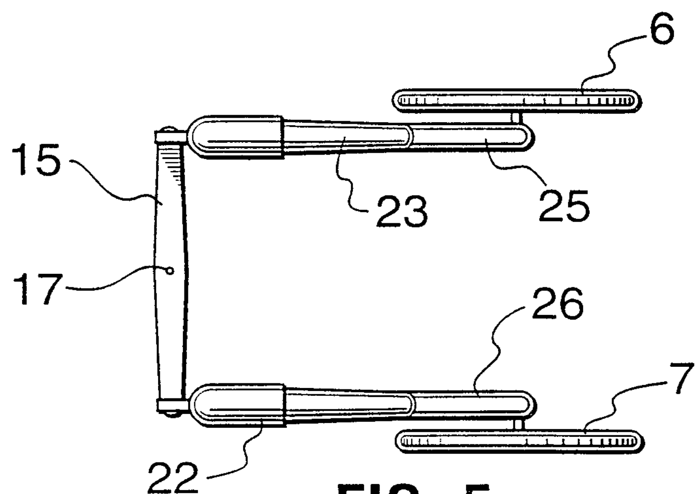


FIG. 5

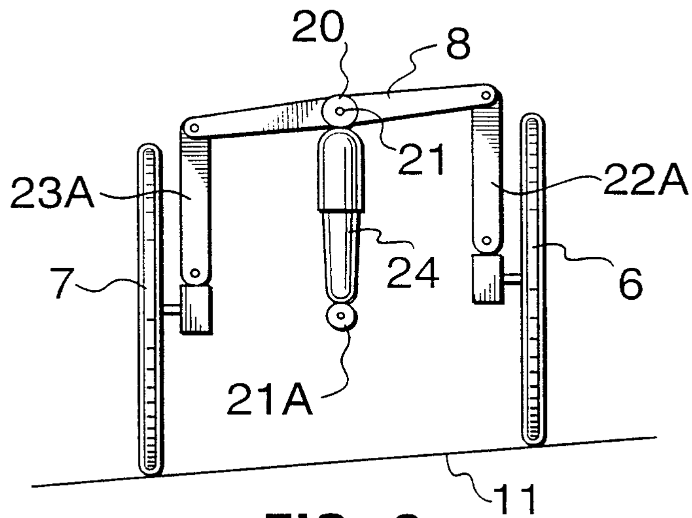
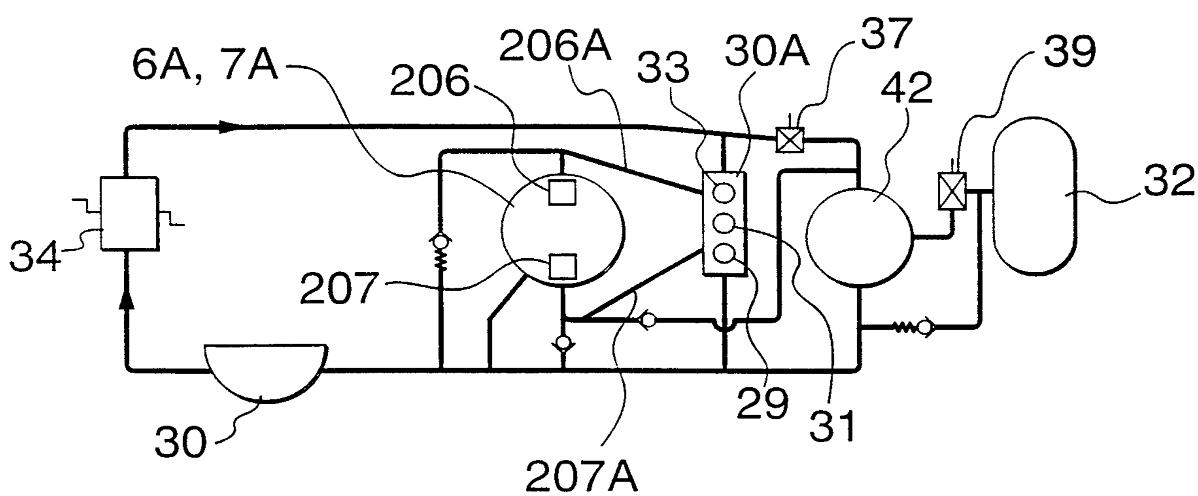

20
8
21
23A
22A
24
7
6
21A
11

FIG. 6


6A, 7A
206A
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30A
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42
32
34
207
30
29
31
207A

FIG. 7

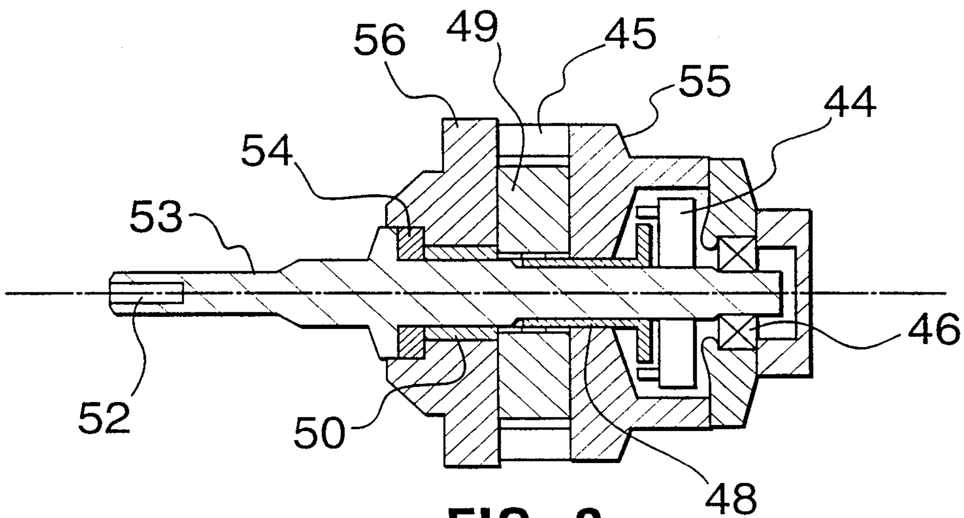


FIG. 8

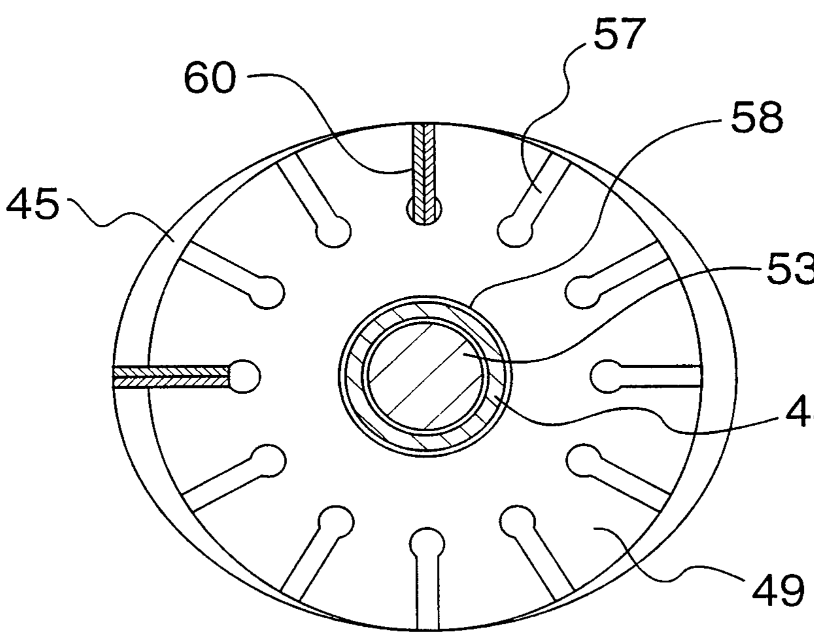


FIG. 9

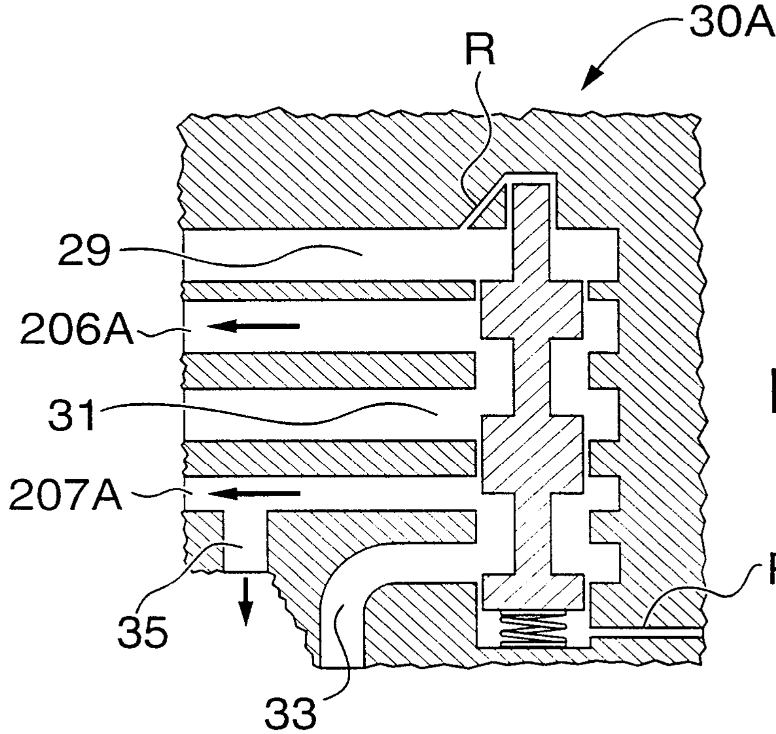


FIG. 10

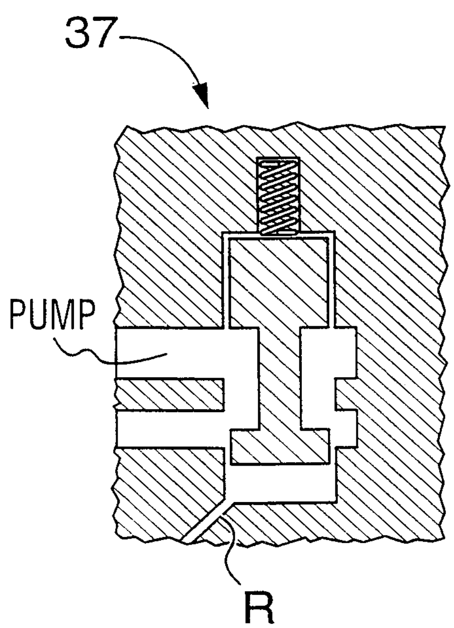


FIG. 11

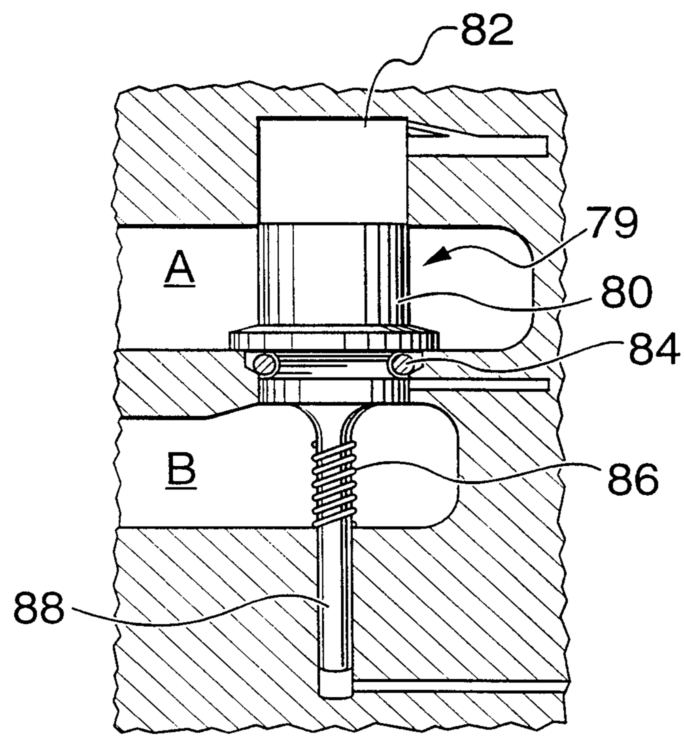


FIG. 12

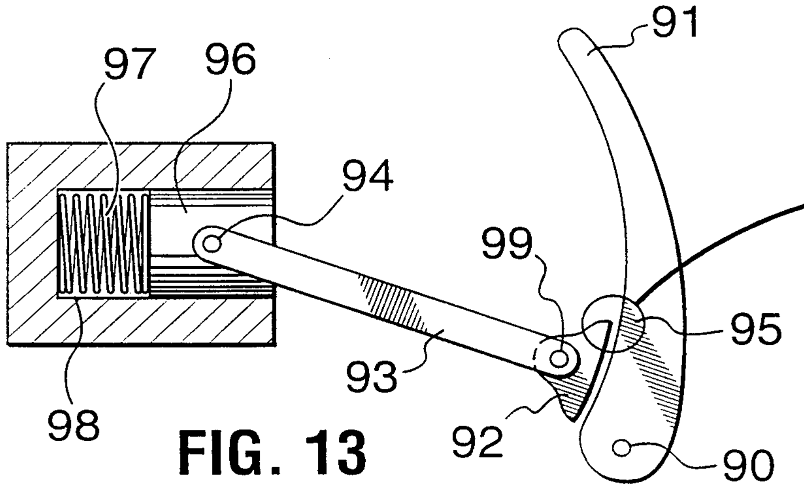


FIG. 13

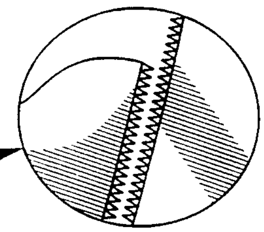


FIG. 14

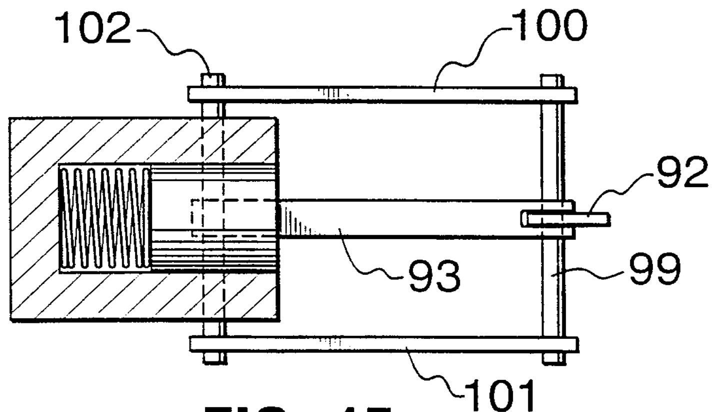


FIG. 15

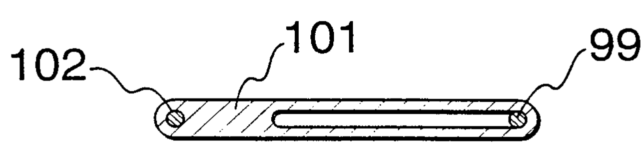


FIG. 16

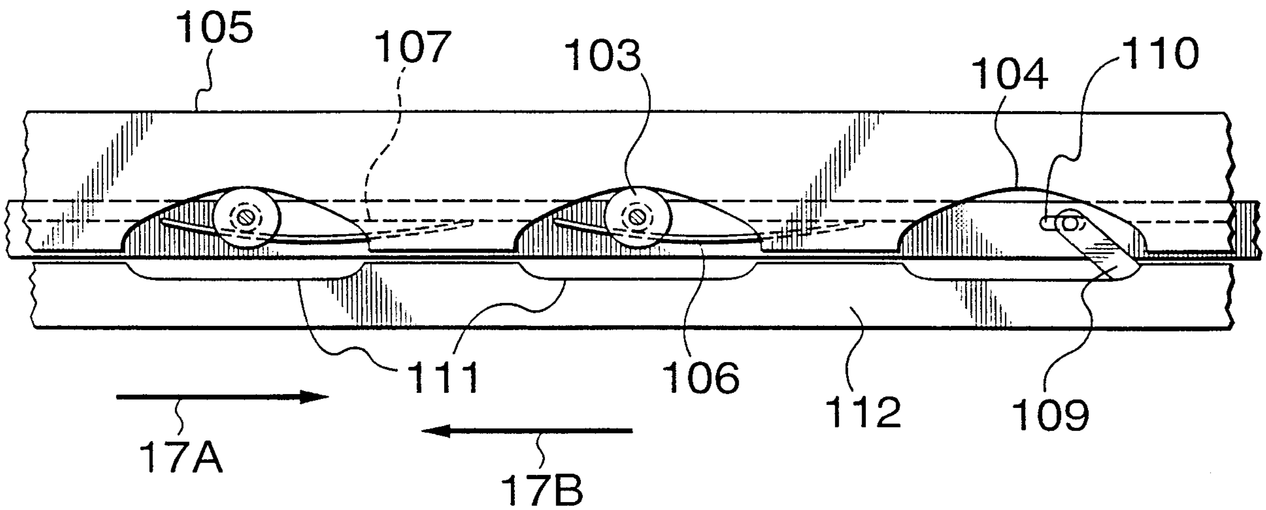


FIG. 17

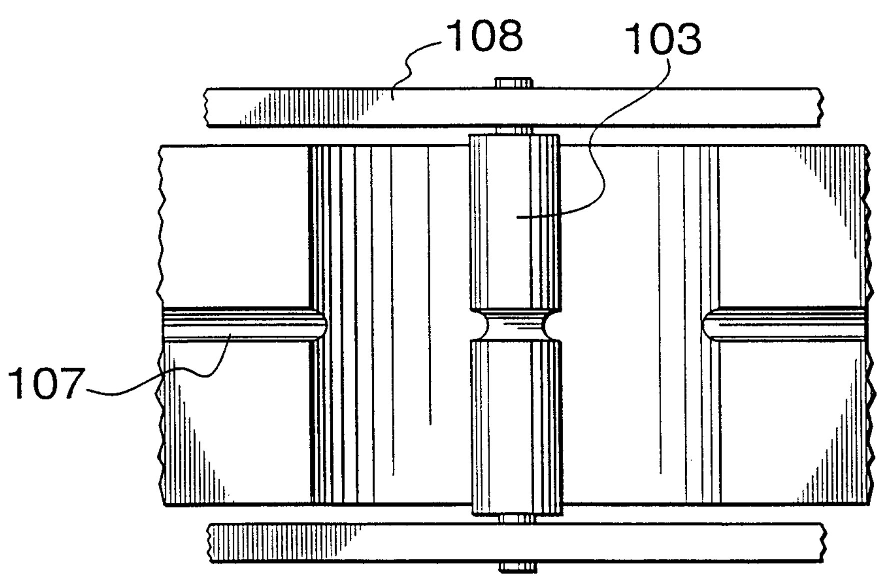


FIG. 18

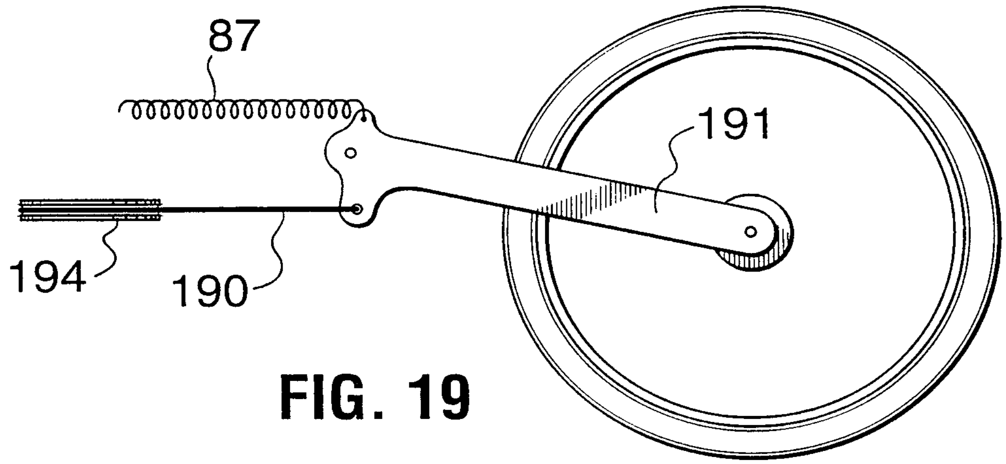


FIG. 19

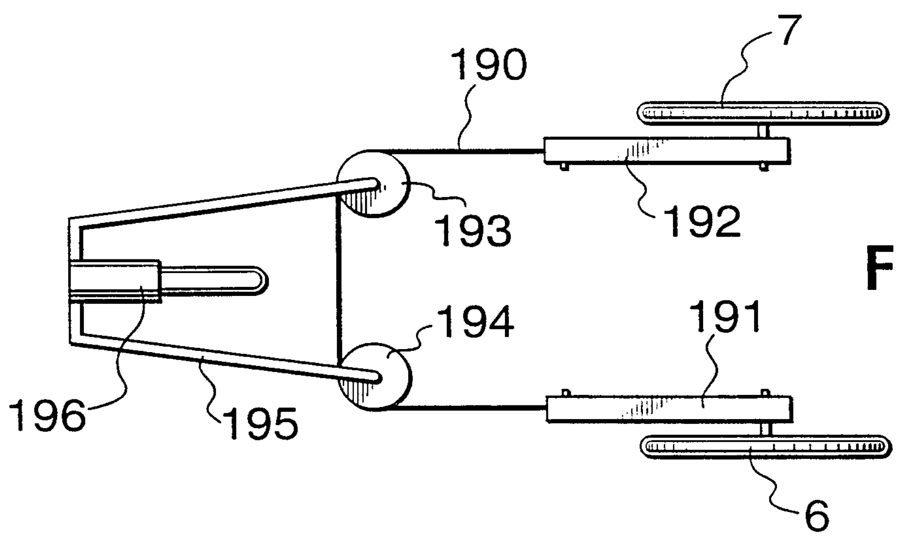


FIG. 20

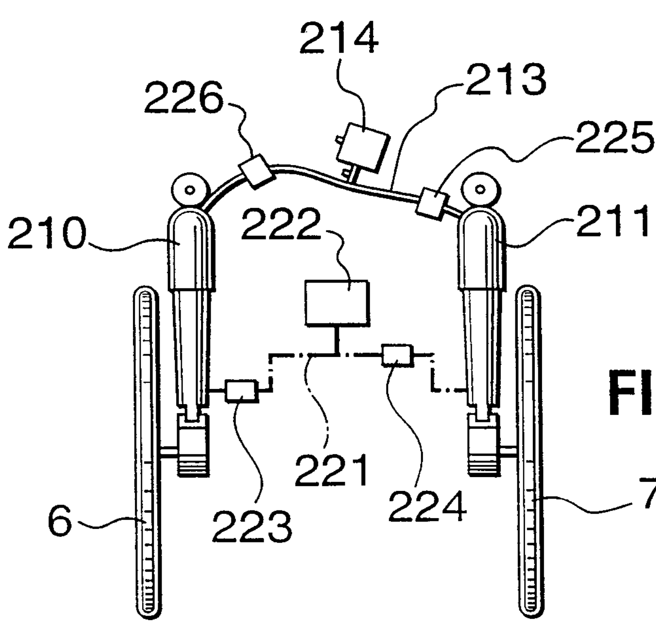


FIG. 21

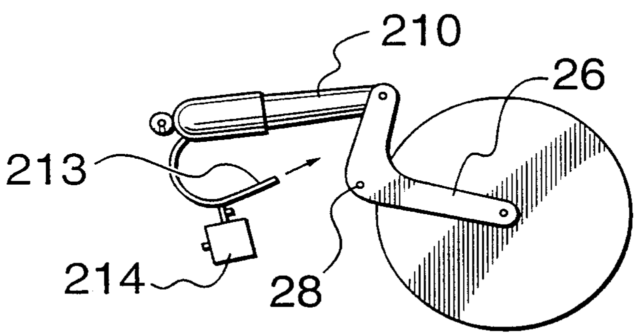


FIG. 22

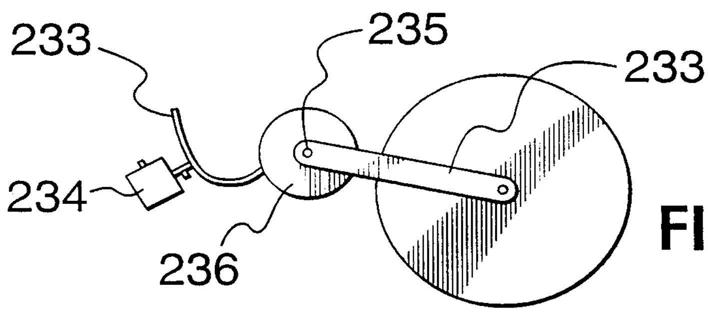


FIG. 23

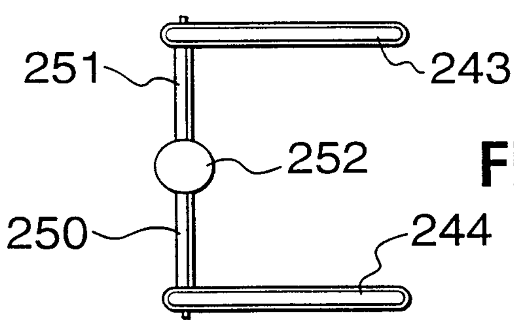


FIG. 24

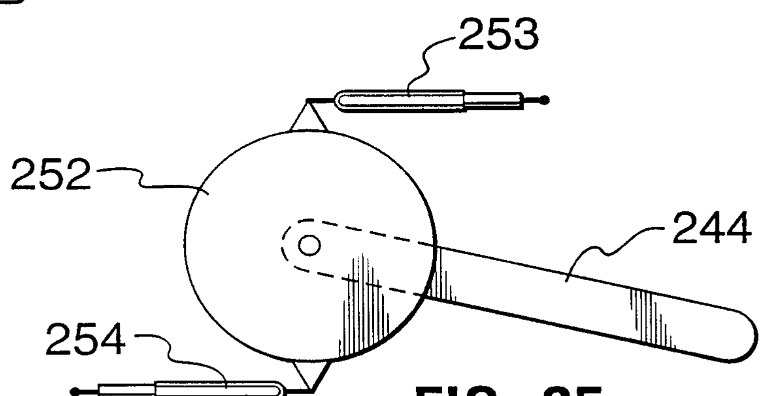
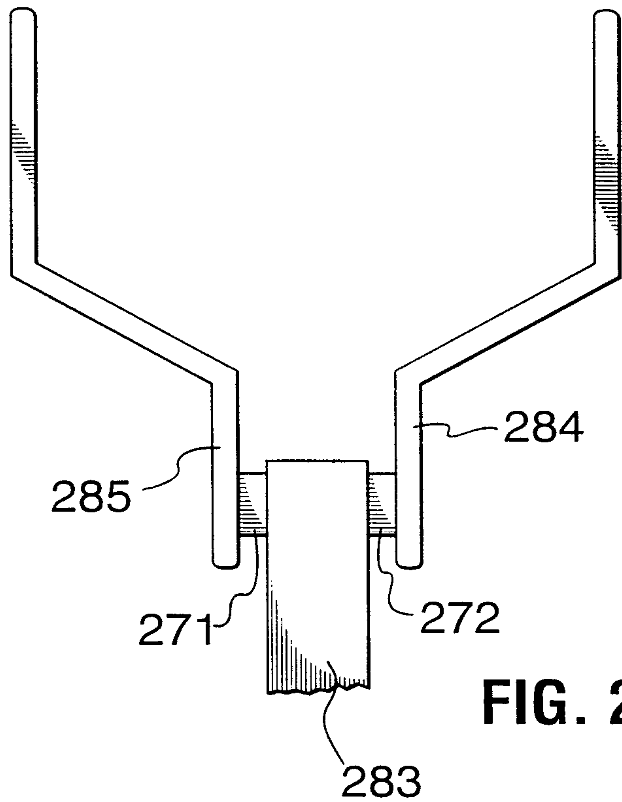


FIG. 25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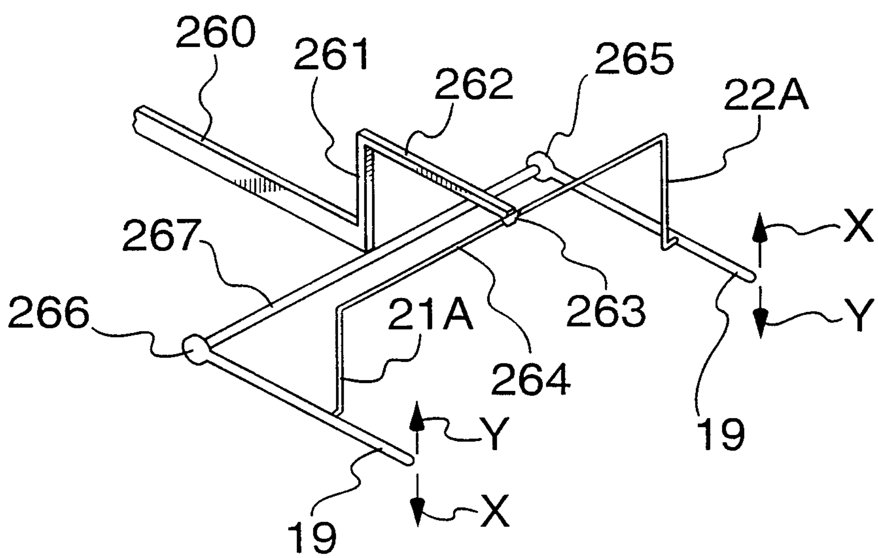
272
283

FIG. 27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22A
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21A
263
264
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Y
X
19

FIG. 26

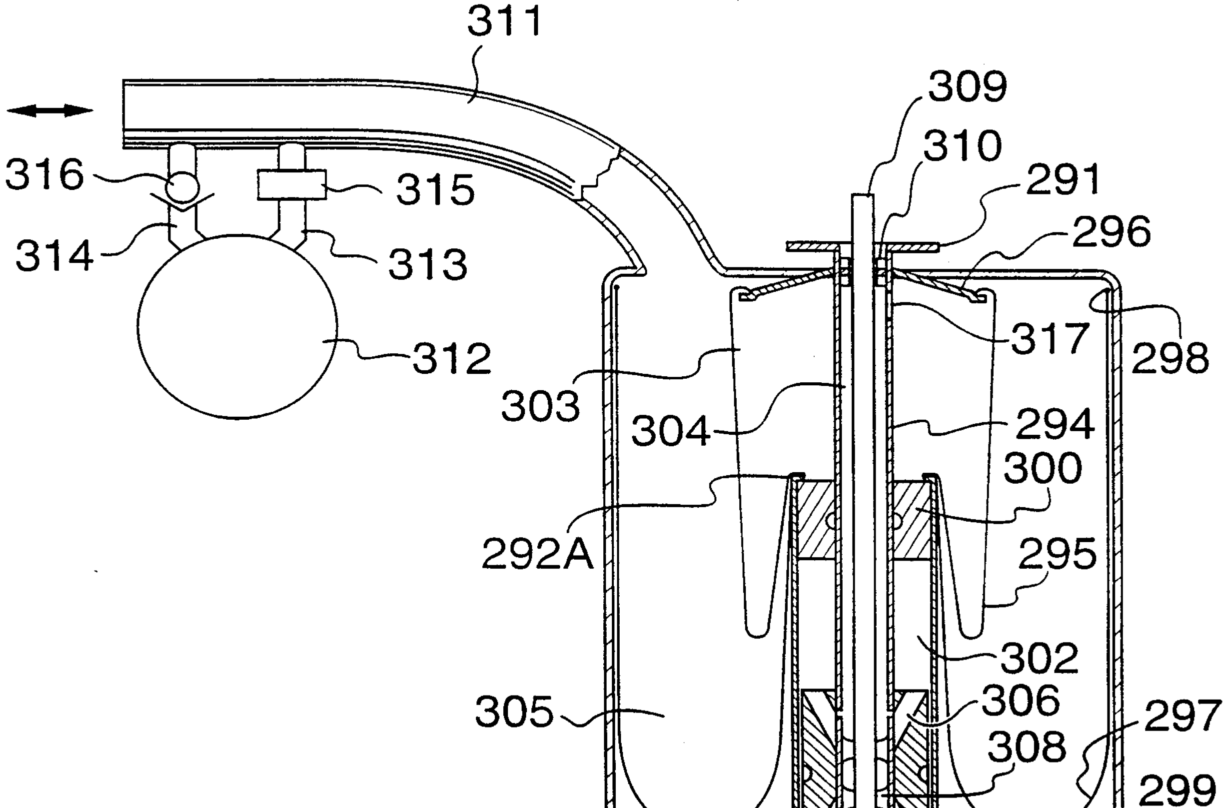
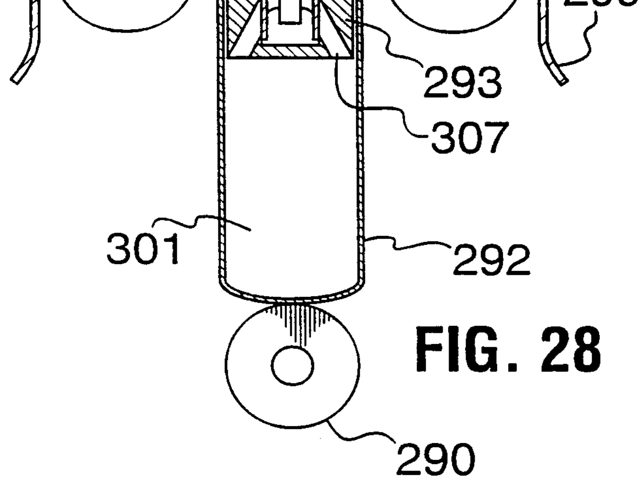



FIG. 28

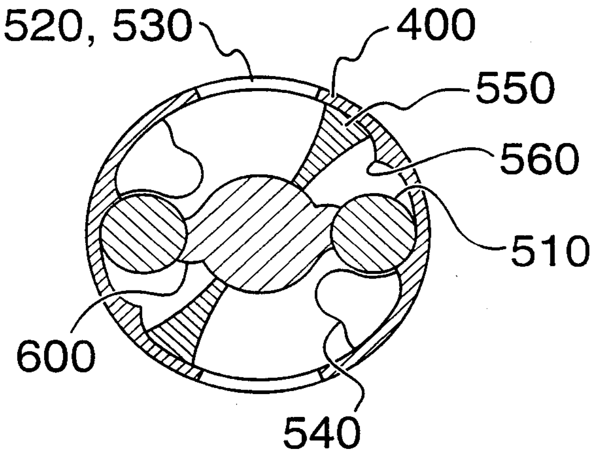
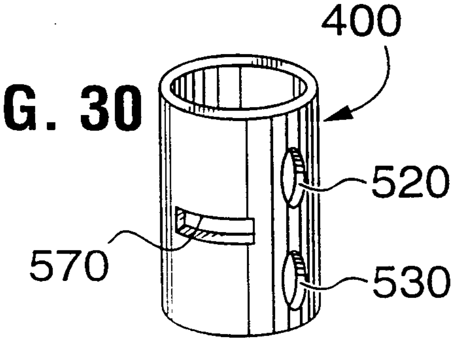


FIG. 29

FIG. 30



INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 99/00488

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B62K5/04 B62M19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B62K B62M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 346 234 A (KADAJA) 13 September 1994 (1994-09-13)	1
A	the whole document	2-10
A	US 5 423 560 A (WARRICK ET AL.) 13 June 1995 (1995-06-13) cited in the application the whole document	1-10
A	US 4 688 815 A (SMITH) 25 August 1987 (1987-08-25) the whole document	1-10
A	FR 2 646 379 A (GIRARDI) 2 November 1990 (1990-11-02) the whole document	1,11-13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
27 August 1999	03/09/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Denicolai, G

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 99/00488

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5346234 A	13-09-1994	NONE	
US 5423560 A	13-06-1995	AU 1940795 A	03-10-1995
		WO 9525036 A	21-09-1995
US 4688815 A	25-08-1987	NONE	
FR 2646379 A	02-11-1990	NONE	